

## CLAIMS

What is claimed is:

- 1 1. An adaptive differential pulse code modulation system comprising:
  - 2 an encoder including:
    - 3 a subtractor configured for deriving a difference signal  $E_j$ , the difference
    - 4 signal  $E_j$  being the difference between an input signal  $Y_j$  and a predicted
    - 5 signal  $S_j$ ,  $j$  representing a sample period;
    - 6 a quantizer configured for quantizing the difference signal  $E_j$  to obtain a
    - 7 numerical representation  $N_j$  for transmission to an encoder inverse quantizer
    - 8 for deriving a regenerated difference signal  $D_j$ , and to a decoder inverse
    - 9 quantizer coupled to the quantizer through a network for deriving the
    - 10 regenerated difference signal  $D_j$ ,
    - 11 an encoder adder configured for deriving a reconstructed input signal  $X_j$ ,
    - 12 the reconstructed input signal  $X_j$  being the sum of the regenerated difference
    - 13 signal  $D_j$  and the predicted signal  $S_j$ ;
    - 14 an encoder whitening filter  $F_e$  configured for receiving the reconstructed
    - 15 input signal  $X_j$  and for generating a filtered reconstructed signal  $X_j^f$ , the
  - 16 
$$X_j^f = X_j - a_1^f X_{j-1} - a_2^f X_{j-2} - \dots - a_n^f X_{j-n}$$
filtered reconstructed signal  $X_j^f$  being generated according to the equation:
  - 17  $X_{j-n}$  being a value of reconstructed input signal  $X_j$  at sample period  $j-n$ ,
  - 18 and;

19  $n$  being a number of filter tap coefficients  $a_n^f$  corresponding to the  
 20 whitening filter  $F_e$ ;  
 21 an encoder predictor  $P_{ep}$  configured for receiving the reconstructed input  
 22 signal  $X_j$  and for generating a predicted signal  $S_{jp}$ , the predicted signal  $S_{jp}$   
 23 being at least constituent to predicted signal  $S_j$  and being generated according  
 24 to the equation:

$$25 \quad S_{jp} = a_1^j S_{j-1} + a_2^j S_{j-2} \dots a_{n_p}^j S_{j-n_p}$$

26  $S_{j-n_p}$  being a value of the predicted signal  $S_j$  at sample period  $j-n_p$ , and  
 27  $n_p$  being a number of predictor coefficients  $a_{n_p}^j$  corresponding to the  
 28 predictor  $P_{ep}$ ; and  
 29 an encoder feedback loop configured for applying the predicted signal  $S_j$   
 30 to the adder;  
 31 transmission means configured for transmitting the numerical  
 32 representation  $N_j$  from the encoder to a decoder; and  
 33 the decoder including:

34 the decoder inverse quantizer coupled to the quantizer through a network  
 35 and configured for receiving the numerical representation  $N_j$  and for deriving  
 36 the regenerated difference signal  $D_j$  therefrom,  
 37 a decoder adder configured for deriving the reconstructed input signal  $X_j$ ,  
 38 the reconstructed input signal  $X_j$  being the sum of the regenerated difference  
 39 signal  $D_j$  and the predicted signal  $S_j$ ;

40 a decoder whitening filter  $F_d$  configured for receiving the reconstructed  
 41 input signal  $X_j$  and for generating the filtered reconstructed signal  $X_j^f$ , the  
 42 filtered reconstructed signal  $X_j^f$  being generated according to the equation:

$$43 \quad X_j^f = X_j - a_{f1}^f X_{j-1} - a_{f2}^f X_{j-2} - \dots - a_{fn}^f X_{j-n}$$

44  $X_{j-n}$  being a value of reconstructed signal  $X_j$  at sample period  $j-n$ , and  
 45  $n$  being the number of filter tap coefficients  $a_{fn}^f$  corresponding to the  
 46 whitening filter  $F_d$ ;

47 a decoder predictor  $P_{dp}$  configured for receiving the reconstructed input  
 48 signal  $X_j$  and for generating a predicted signal  $S_{jp}$ , the predicted signal  $S_{jp}$   
 49 being at least constituent to predicted signal  $S_j$  and being generated according  
 50 to the equation:

$$51 \quad S_{jp} = a_1^j S_{j-1} + a_2^j S_{j-2} \dots a_{np}^j S_{j-np}$$

52  $S_{j-np}$  being a value of the predicted signal  $S_j$  at sample period  $j-n_p$ , and  
 53  $n_p$  being the number of predictor coefficients  $a_{np}^j$  corresponding to the  
 54 predictor  $P_{dp}$ ; and

55 a decoder feedback loop configured for applying the predicted signal  $S_j$  to  
 56 the decoder adder.

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1 2. The system of claim 1, further comprising:

2 a second encoder predictor  $P_{ez}$  configured for receiving the regenerated  
 3 difference signal  $D_j$  and for generating a predicted signal  $S_{jz}$ ;

4 a second encoder adder configured for deriving the predicted signal  $S_j$  at  
5 the encoder, the predicted signal  $S_j$  being the sum of the predicted signal  $S_{jp}$  and  
6 the predicted signal  $S_{jz}$ ;  
7 a second decoder predictor  $P_{dz}$  configured for receiving the regenerated  
8 difference signal  $D_j$  and for generating a predicted signal  $S_{jz}$ ; and  
9 a second decoder adder configured for deriving the predicted signal  $S_j$  at  
10 the decoder, the predicted signal  $S_j$  being the sum of the predicted signal  $S_{jp}$  and  
11 the predicted signal  $S_{jz}$ .

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1 3. The system of claim 1 wherein:

2  $n_p$  is 2;

3 the predictor coefficient  $a_1^j$  is updated according to the equation:

$$4 \quad a_1^{j+1} = a_1^j(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

5  $\delta_1$  and  $g_1$  being proper positive constants, and

6  $F_1$  being a nonlinear function; and

7 the predictor coefficient  $a_2^j$  is updated according to the equation:

$$8 \quad a_2^{j+1} = a_2^j(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^j);$$

9  $\delta_2$  and  $g_2$  being proper positive constants, and

10  $F_2$  being a nonlinear function.

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1 4. The system of claim 1 wherein:

2  $n$  is 2;

3 the filter tap coefficient  $a_1^f$  is updated at each sample period  $j$  according to

4 the generalized equation:

$$5 \quad a_1^{fj+1} = a_1^{fj}(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

6  $\delta_1$  and  $g_1$  being proper positive constants, and

7  $F_1$  being a nonlinear function; and

8 the filter tap coefficients  $a_2^f$  is updated at each sample period  $j$  according to

9 the generalized equation:

$$10 \quad a_2^{fj+1} = a_2^{fj}(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^{fj})$$

11  $\delta_2$  and  $g_2$  being proper positive constants, and

12  $F_2$  being a nonlinear function.

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1 5. The system of claim 4 wherein:

2 the filter tap coefficient  $a_1^{fj}$  is updated according to the equation:

$$3 \quad a_1^{fj+1} = a_1^{fj} \left( 1 - \left( \frac{128}{32768} \right) \right) + 192 * \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f]; \text{ and}$$

4 the filter tap coefficient  $a_2^{fj}$  is updated according to the equation:

$$5 \quad a_2^{fj+1} = a_2^{fj} \left( 1 - \left( \frac{256}{32768} \right) \right) - \left( \frac{1}{32} \right) a_1^{fj} \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] + 128 * \text{sgn}[X_j^f] \text{sgn}[X_{j-2}^f];$$

6  $\text{sgn}[\ ]$  being a sign function that returns a value of 1 for a nonnegative

7 argument and a value of -1 for a negative argument.

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1 6. The system of claim 5 wherein at every other sample period  $j$ ,  
2 the filter tap coefficient  $a^{f+1}_2$  is maintained in a range  $-12288 \leq a^{f+1}_2 \leq$   
3 12288; and  
4 the filter tap coefficient  $a^{f+1}_1$  is maintained in a range  $-(15360 - a^{f+1}_2) \leq$   
5  $a^{f+1}_1 \leq (15360 - a^{f+1}_2)$ ;  
6 whereby  $a^{f+1}_1$  is set equal to  $(15360 - a^{f+1}_2)$  when  $a^{f+1}_1 > 15360 - a^{f+1}_2$ ; and  
7 whereby  $a^{f+1}_1$  is set equal to  $-(15360 - a^{f+1}_2)$  when  $a^{f+1}_1 < -(15360 - a^{f+1}_2)$ .

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1 7. The system of claim 5, further comprising:  
2 a second encoder predictor  $P_{ez}$  configured for receiving the regenerated  
3 difference signal  $D_j$  and for generating a predicted signal  $S_{jz}$ ;  
4 a second encoder adder configured for deriving the predicted signal  $S_j$  at  
5 the encoder, the predicted signal  $S_j$  being the sum of the predicted signal  $S_{jp}$  and  
6 the predicted signal  $S_{jz}$ ;  
7 a second decoder predictor  $P_{dz}$  configured for receiving the regenerated  
8 difference signal  $D_j$  and for generating a predicted signal  $S_{jz}$ ; and  
9 a second decoder adder configured for deriving the predicted signal  $S_j$  at  
10 the decoder, the predicted signal  $S_j$  being the sum of the predicted signal  $S_{jp}$  and  
11 the predicted signal  $S_{jz}$ .

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1 8. The system of claim 1 wherein at every other sample period  $j$ , the predictor  
 2 coefficient  $a_{np}$  corresponding to the predictors  $P_{ep}$  and  $P_{dp}$  is maintained  
 3 unchanged.

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1 9. The system of claim 8, such that if for even  $j$ :

$$2 \quad a_1^{j+1} = a_1^j, \text{ and}$$

$$3 \quad a_2^{j+1} = a_2^j,$$

4 then for odd  $j$ :

$$5 \quad a_1^{j+1} = a_1^{j-1} \left( 1 - \left( \frac{127.5}{32768} \right) \right) + 191.25 * \text{sgn}[X_{j-1}^f] \text{sgn}[X_{j-2}^f] + 192 * \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f], \text{ and}$$

$$6 \quad a_2^{j+1} = a_2^{j-1} \left( 1 - \left( \frac{510}{32768} \right) \right) - \left( \frac{1016}{32768} \right) \lim[a_1^{j-1}] \text{sgn}[X_{j-1}^f] \text{sgn}[X_{j-2}^f] + 127 * \text{sgn}[X_{j-1}^f] \text{sgn}[X_{j-3}^f] \\ - \left( \frac{1}{32} \right) \lim[a_1^{j-1}] \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] + 128 * \text{sgn}[X_j^f] \text{sgn}[X_{j-2}^f],$$

7  $\text{sgn}[\ ]$  being a sign function that returns a value of 1 for a nonnegative  
 8 argument and a value of -1 for a negative argument, and

$$9 \quad \lim[a_1^{j-1}] = a_1^{j-1} \text{ for } -8192 \leq a_1^{j-1} \leq 8191,$$

$$10 \quad \lim[a_1^{j-1}] = -8192 \text{ for } a_1^{j-1} < -8191, \text{ and}$$

$$11 \quad \lim[a_1^{j-1}] = 8192 \text{ for } a_1^{j-1} > 8191.$$

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10. An encoder for encoding digital audio signals, comprising:

a subtractor configured for deriving a difference signal  $E_j$ , the difference signal  $E_j$  being the difference between an input signal  $Y_j$  and a predicted signal  $S_j$ ,  $j$  representing a sample period;

a quantizer configured for quantizing the difference signal  $E_j$  to obtain a numerical representation  $N_j$  for transmission to an encoder inverse quantizer for deriving a regenerated difference signal  $D_j$ , and to a decoder inverse quantizer coupled to the quantizer for deriving the regenerated difference signal  $D_j$ ;

an adder configured for deriving a reconstructed input signal  $X_j$ , the reconstructed input signal  $X_j$  being the sum of the regenerated difference signal  $D_j$  and the predicted signal  $S_j$ ;

a whitening filter configured for receiving the reconstructed input signal  $X_j$  and for generating a filtered reconstructed signal  $X_j^f$ , the filtered reconstructed signal  $X_j^f$  being generated according to the equation:

$$X_j^f = X_j - a_1^f X_{j-1} - a_2^f X_{j-2} - \dots - a_n^f X_{j-n}^f$$

$X_{j-n}^f$  being a value of filtered reconstructed signal  $X_j^f$  at sample period  $j-n$ ,  
and  
 $n$  being a number of filter tap coefficients  $a_n^f$  corresponding to the whitening filter;

a predictor configured for receiving the reconstructed input signal  $X_j$  and for generating a predicted signal  $S_{jp}$ , the predicted signal  $S_{jp}$  being at least



23 constituent to predicted signal  $S_j$  and being generated according to the  
24 equation:

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$$S_{jp} = a_{j1} S_{j-1} - a_{j2} S_{j-2} - \dots a_{jnp} S_{j-np}$$

26  $S_{j-np}$  being a value of the predicted signal  $S_j$  at sample period  $j-n_p$ , and  
27  $n_p$  being a number of predictor coefficients  $a_{jnp}$  corresponding to the  
28 predictor; and  
29 a feedback loop configured for applying the predicted signal  $S_j$  to the  
30 adder.

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1 11. The system of claim 10, the encoder further comprising:

2 a second predictor configured for receiving the regenerated difference  
3 signal  $D_j$  and for generating a predicted signal  $S_{jz}$ , the predicted signal  $S_{jz}$  being  
4 at least constituent to predicted signal  $S_j$ ; and

5 a second adder configured for deriving the predicted signal  $S_j$ , the  
6 predicted signal  $S_j$  being the sum of the predicted signal  $S_{jp}$  and the predicted  
7 signal  $S_{jz}$ .

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1 12. The system of claim 10 wherein:

2  $n$  is 2;

3 the filter tap coefficient  $a_1^f$  is updated at each sample period  $j$  according to  
4 the generalized equation:

$$a_1^{fj+1} = a_1^{fj}(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

$\delta_1$  and  $g_1$  being proper positive constants, and

$F_1$  being a nonlinear function;

the filter tap coefficients  $a_2^f$  is updated at each sample period  $j$  according to the generalized equation:

$$a_2^{fj+1} = a_2^{fj}(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^{fj})$$

$\delta_2$  and  $g_2$  being proper positive constants, and

$F_2$  being a nonlinear function.

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13. The system of claim 12 wherein:

the filter tap coefficient  $a_1^f$  is updated according to the equation:

$$a_1^{fj+1} = a_1^{fj} \left( 1 - \left( \frac{128}{32768} \right) \right) + 192 * \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] \text{ and}$$

the filter tap coefficient  $a_2^f$  is updated according to the equation:

$$a_2^{fj+1} = a_2^{fj} \left( 1 - \left( \frac{256}{32768} \right) \right) - \left( \frac{1}{32} \right) a_1^{fj} \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] + 128 * \text{sgn}[X_j^f] \text{sgn}[X_{j-2}^f],$$

$\text{sgn}[\ ]$  being a sign function that returns a value of 1 for a nonnegative argument and a value of -1 for a negative argument.

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14. The system of claim 13 wherein at every other sample period  $j$ ,

the filter tap coefficient  $a^{fj+1}_2$  is maintained in a range  $-12288 \leq a^{fj+1}_2 \leq$

12288; and

4 the filter tap coefficient  $a^{f+1}_1$  is maintained in a range  $-(15360 - a^{f+1}_2) \leq$   
5  $a^{f+1}_1 \leq (15360 - a^{f+1}_2)$ ;  
6 whereby  $a^{f+1}_1$  is set equal to  $(15360 - a^{f+1}_2)$  when  $a^{f+1}_1 > 15360 - a^{f+1}_2$ ; and  
7 whereby  $a^{f+1}_1$  is set equal to  $-(15360 - a^{f+1}_2)$  when  $a^{f+1}_1 < -(15360 - a^{f+1}_2)$ .

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1 15. The system of claim 10 wherein at every other sample period  $j$ , the predictor  
2 coefficient  $a_{np}$  corresponding to the predictor is maintained unchanged.

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1 16. The system of claim 10, wherein the encoder is constituent to or coupled to a  
2 videoconferencing device or application.

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- 1 17. A decoder for decoding digital audio signals encoded by a properly
- 2 associated encoder, comprising:
- 3 an inverse quantizer coupled to the encoder and configured for receiving
- 4 a numerical representation  $N_j$  and for deriving a regenerated difference signal
- 5  $D_j$  therefrom, the numerical representation  $N_j$  being a quantized
- 6 representation of a difference signal  $E_j$ , the difference signal  $E_j$  being the
- 7 difference between an input signal  $Y_j$  and a predicted signal  $S_j$ ,  $j$  representing
- 8 a sample period;
- 9 an adder configured for deriving a reconstructed input signal  $X_j$ , the
- 10 reconstructed input signal  $X_j$  being the sum of the regenerated difference
- 11 signal  $D_j$  and the predicted signal  $S_j$ ;
- 12 a whitening filter configured for receiving the reconstructed input signal
- 13  $X_j$  and for generating a filtered reconstructed signal  $X_j^f$ , the filtered
- 14 reconstructed signal  $X_j^f$  being generated according to the equation:
- 15 
$$X_j^f = X_j - a_{f1}^f X_{j-1} - a_{f2}^f X_{j-2} - \dots - a_{fn}^f X_{j-n}^f$$
- 16  $X_{j-n}^f$  being a value of filtered reconstructed signal  $X_j^f$  at sample period  $j-n$ ,
- 17 and
- 18  $n$  being a number of filter tap coefficients  $a_{fn}^f$  corresponding to the
- 19 whitening filter;
- 20 a predictor configured for receiving the reconstructed input signal  $X_j$  and
- 21 for generating a predicted signal  $S_{jp}$ , the predicted signal  $S_{jp}$  being at least

22 constituent to predicted signal  $S_j$  and being generated according to the  
23 equation:

24 
$$S_{jp} = a_{j1} S_{j-1} - a_{j2} S_{j-2} - \dots - a_{jnp} S_{j-np}$$

25  $S_{j-np}$  being a value of the predicted signal  $S_j$  at sample period  $j-n_p$ , and

26  $n_p$  being a number of predictor coefficients  $a_{jnp}$  corresponding to the

27 predictor; and

28 a feedback loop configured for applying the predicted signal  $S_j$  to the  
29 adder.

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1 18. The system of claim 17, the decoder further comprising:

2 a second predictor configured for receiving the regenerated difference  
3 signal  $D_j$  and for generating a predicted signal  $S_{jz}$ , the predicted signal  $S_{jz}$  being  
4 at least constituent to predicted signal  $S_j$ ; and

5 a second adder configured for deriving the predicted signal  $S_j$ , the  
6 predicted signal  $S_j$  being the sum of the predicted signal  $S_{jp}$  and the predicted  
7 signal  $S_{jz}$ .

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1 19. The system of claim 17 wherein:

2  $n$  is 2;

3 the filter tap coefficient  $a_1^f$  is updated at each sample period  $j$  according to

4 the generalized equation:

$$a_1^{fj+1} = a_1^{fj}(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

$\delta_1$  and  $g_1$  being proper positive constants, and

$F_1$  being a nonlinear function;

the filter tap coefficients  $a_2^f$  is updated at each sample period  $j$  according to the generalized equation:

$$a_2^{fj+1} = a_2^{fj}(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^{fj})$$

$\delta_2$  and  $g_2$  being proper positive constants, and;

$F_2$  being a nonlinear function.

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20. The system of claim 19 wherein:

the filter tap coefficient  $a_1^f$  is updated according to the equation:

$$a_1^{fj+1} = a_1^{fj} \left( 1 - \left( \frac{128}{32768} \right) \right) + 192 * \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] \text{ and}$$

the filter tap coefficient  $a_2^f$  is updated according to the equation:

$$a_2^{fj+1} = a_2^{fj} \left( 1 - \left( \frac{256}{32768} \right) \right) - \left( \frac{1}{32} \right) a_1^{fj} \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] + 128 * \text{sgn}[X_j^f] \text{sgn}[X_{j-2}^f]$$

$\text{sgn}[\ ]$  being a sign function that returns a value of 1 for a nonnegative argument and a value of -1 for a negative argument.

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21. The system of claim 20 wherein at every other sample period  $j$ ,

the filter tap coefficient  $a_1^{fj+1}$  is maintained in a range  $-12288 \leq a_1^{fj+1} \leq$

12288; and

4 the filter tap coefficient  $a^{f+1}_1$  is maintained in a range  $-(15360 - a^{f+1}_2) \leq$

5  $a^{f+1}_1 \leq (15360 - a^{f+1}_2)$ ;

6 whereby  $a^{f+1}_1$  is set equal to  $(15360 - a^{f+1}_2)$  when  $a^{f+1}_1 > 15360 - a^{f+1}_2$ ; and

7 whereby  $a^{f+1}_1$  is set equal to  $-(15360 - a^{f+1}_2)$  when  $a^{f+1}_1 < -(15360 - a^{f+1}_2)$ .

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1 22. The system of claim 17 wherein at every other sample period  $j$ , the predictor

2 coefficient  $a_{hp}$  corresponding to the predictor is maintained unchanged.

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1 23. The system of claim 17, wherein the decoder is constituent to or coupled to a

2 videoconferencing device or application.

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- 1 24. A method for encoding and decoding digital audio signals, comprising the
- 2 steps of:
- 3 deriving a difference signal  $E_j$  at an encoder, the difference signal  $E_j$  being
- 4 the difference between an input signal  $Y_j$  and a predicted signal  $S_j$ ,  $j$
- 5 representing a sample period;
- 6 quantizing the difference signal  $E_j$  to obtain a numerical representation  $N_j$
- 7 for transmitting to an encoder inverse quantizer for deriving a regenerated
- 8 difference signal  $D_j$ , and to a decoder inverse quantizer coupled to the
- 9 quantizer through a network for deriving the regenerated difference signal
- 10  $D_j$ ;
- 11 deriving a reconstructed input signal  $X_j$  at a first adder, the reconstructed
- 12 input signal  $X_j$  being the sum of the regenerated difference signal  $D_j$  and the
- 13 predicted signal  $S_j$ ;
- 14 receiving the reconstructed input signal  $X_j$  at a whitening filter  $F_e$ ;
- 15 generating a filtered reconstructed signal  $X_j^f$  by the whitening filter  $F_e$ , the
- 16 filtered reconstructed signal  $X_j^f$  being generated according to the equation:
- 17 
$$X_j^f = X_j - a_1^f X_{j-1} - a_2^f X_{j-2} - \dots - a_n^f X_{j-n}^f$$
- 18  $X_{j-n}^f$  being a value of filtered reconstructed signal  $X_j^f$  at sample period  $j-n$ ,
- 19 and
- 20  $n$  being a number of filter tap coefficients  $a_n^f$  corresponding to the
- 21 whitening filter  $F_e$ ;
- 22 receiving the reconstructed input signal  $X_j$  at a predictor  $P_{ep}$ ;



23 generating a predicted signal  $S_{jp}$  by the predictor  $P_{ep}$ , the predicted signal  
 24  $S_{jp}$  being at least constituent to predicted signal  $S_j$  and being generated  
 25 according to the equation:

$$26 \quad S_{jp} = a_{j1} S_{j-1} - a_{j2} S_{j-2} - \dots - a_{jnp} S_{j-np}$$

27  $S_{j-np}$  being a value of the predicted signal  $S_j$  at sample period  $j-n_p$ , and  
 28  $n_p$  being a number of predictor coefficients  $a_{jnp}$  corresponding to the  
 29 predictor  $P_{ep}$ ;

30 applying the predicted signal  $S_j$  to the first adder to provide feedback;  
 31 receiving the numerical representation  $N_j$  at a decoder;

32 deriving the regenerated difference signal  $D_j$  from the numerical  
 33 representation  $N_j$ ,

34 deriving the reconstructed input signal  $X_j$  at a second adder, the  
 35 reconstructed input signal  $X_j$  being the sum of the regenerated difference  
 36 signal  $D_j$  and the predicted signal  $S_j$ ;

37 receiving the reconstructed input signal  $X_j$  at a whitening filter  $F_d$ ;

38 generating a filtered reconstructed signal  $X_j^f$  by the whitening filter  $F_d$ , the  
 39 filtered reconstructed signal  $X_j^f$  being generated according to the equation:

$$40 \quad X_j^f = X_j - a_{j1}^f X_{j-1} - a_{j2}^f X_{j-2} - \dots - a_{jn}^f X_{j-n}$$

41  $X_{j-n}^f$  being a value of filtered reconstructed signal  $X_j^f$  at sample period  $j-n$ ;  
 42  $n$  being a number of filter tap coefficients  $a_{jn}^f$  corresponding to the  
 43 whitening filter  $F_d$ ;

44 receiving the reconstructed input signal  $X_j$  at a predictor  $P_{dp}$ ;

45 generating a predicted signal  $S_{jp}$  by the predictor  $P_{dp}$ , the predicted signal  
46  $S_{jp}$  being at least constituent to predicted signal  $S_j$  and being generated  
47 according to the equation:

48 
$$S_{jp} = a_{j1} S_{j-1} - a_{j2} S_{j-2} - \dots - a_{jnp} S_{j-np}$$

49  $S_{j-np}$  being a value of the predicted signal  $S_j$  at sample period  $j-n_p$ , and  
50  $n_p$  being a number of predictor coefficients  $a_{jnp}$  corresponding to the  
51 predictor  $P_{dp}$ ; and  
52 applying the predicted signal  $S_j$  to the second adder to provide feedback.

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1 25. The method of claim 24, further comprising the steps of:

2 receiving the regenerated difference signal  $D_j$  at a predictor  $P_{ez}$  at the  
3 encoder;

4 generating a predicted signal  $S_{jz}$  by the predictor  $P_{ez}$ ;

5 deriving the predicted signal  $S_j$  at the encoder, the predicted signal  $S_j$   
6 being the sum of the predicted signal  $S_{jp}$  and the predicted signal  $S_{jz}$ ;

7 receiving the regenerated difference signal  $D_j$  at a predictor  $P_{dz}$  at the  
8 decoder;

9 generating the predicted signal  $S_{jz}$  by the predictor  $P_{dz}$ ; and

10 deriving the predicted signal  $S_j$  at the decoder, the predicted signal  $S_j$   
11 being the sum of the predicted signal  $S_{jp}$  and the predicted signal  $S_{jz}$ .

1

1 26. The method of claim 24 wherein  $n_p$  is 2, further comprising the steps of:

2 updating the predictor coefficient  $a_1^j$  according to the equation:

3 
$$a_1^{j+1} = a_1^j(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

4  $\delta_1$  and  $g_1$  being proper positive constants, and

5  $F_1$  being a nonlinear function; and

6 updating the predictor coefficient  $a_2^j$  according to the equation:

7 
$$a_2^{j+1} = a_2^j(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^j)$$

8  $\delta_2$  and  $g_2$  being proper positive constants, and;

9  $F_2$  being a nonlinear function.

1

1 27. The method of claim 24 wherein  $n$  is 2, further comprising the steps of:

2 updating the filter tap coefficient  $a_1^f$  at each sample period  $j$  according to

3 the generalized equation:

4 
$$a_1^{fj+1} = a_1^{fj}(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

5  $\delta_1$  and  $g_1$  being proper positive constants, and

6  $F_1$  being a nonlinear function; and

7 updating the filter tap coefficients  $a_2^f$  at each sample period  $j$  according to

8 the generalized equation:

9 
$$a_2^{fj+1} = a_2^{fj}(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^{fj})$$

10  $\delta_2$  and  $g_2$  being proper positive constants, and

11  $F_2$  being a nonlinear function.

1

1 28. The method of claim 27 wherein:

2 the filter tap coefficient  $a_1^f$  is updated according to the equation:

3 
$$a_1^{f,j+1} = a_1^{f,j} \left( 1 - \left( \frac{128}{32768} \right) \right) + 192 * \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f], \text{ and}$$

4 the filter tap coefficient  $a_2^f$  is updated according to the equation:

5 
$$a_2^{f,j+1} = a_2^{f,j} \left( 1 - \left( \frac{256}{32768} \right) \right) - \left( \frac{1}{32} \right) a_1^{f,j} \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] + 128 * \text{sgn}[X_j^f] \text{sgn}[X_{j-2}^f]$$

6  $\text{sgn}[\ ]$  being a sign function that returns a value of 1 for a nonnegative  
7 argument and a value of -1 for a negative argument.

1 29. The method of claim 28 wherein at every other sample period  $j$ ,

2 the filter tap coefficient  $a^{f+1}_2$  is maintained in a range  $-12288 \leq a^{f+1}_2 \leq$   
3  $12288$ ; and

4 the filter tap coefficient  $a^{f+1}_1$  is maintained in a range  $-(15360 - a^{f+1}_2) \leq$   
5  $a^{f+1}_1 \leq (15360 - a^{f+1}_2)$ ;

6 whereby  $a^{f+1}_1$  is set equal to  $(15360 - a^{f+1}_2)$  when  $a^{f+1}_1 > 15360 - a^{f+1}_2$ ; and

7 whereby  $a^{f+1}_1$  is set equal to  $-(15360 - a^{f+1}_2)$  when  $a^{f+1}_1 < -(15360 - a^{f+1}_2)$ .

1 30. The method of claim 28, further comprising the steps of:

2 receiving the regenerated difference signal  $D_j$  at a predictor  $P_{ez}$  at the  
3 encoder;

4 generating a predicted signal  $S_{jz}$  by the predictor  $P_{dz}$ ;

5 deriving the predicted signal  $S_j$  at the encoder, the predicted signal  $S_j$   
 6 being the sum of the predicted signal  $S_{jp}$  and the predicted signal  $S_{jz}$ ;  
 7 receiving the regenerated difference signal  $D_j$  at a predictor  $P_{dz}$  at the  
 8 decoder;  
 9 generating the predicted signal  $S_{jz}$  by the predictor  $P_{dz}$ ; and  
 10 deriving the predicted signal  $S_j$  at the decoder, the predicted signal  $S_j$   
 11 being the sum of the predicted signal  $S_{jp}$  and the predicted signal  $S_{jz}$ .

1 31. The method of claim 28 wherein  $n_p$  is 2, further comprising the steps of:

2 updating the predictor coefficient  $a_1^j$  according to the equation:

$$3 \quad a_1^{j+1} = a_1^j(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

4  $\delta_1$  and  $g_1$  being proper positive constants, and

5  $F_1$  being a nonlinear function; and

6 updating the predictor coefficient  $a_2^j$  according to the equation:

$$7 \quad a_2^{j+1} = a_2^j(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^j)$$

8  $\delta_2$  and  $g_2$  being proper positive constants, and;

9  $F_2$  being a nonlinear function.

1

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1 32. A method for adapting coefficients in a two pole predictor in an adaptive  
2 differential pulse code modulation system, comprising the steps of:

3 generating a filtered reconstructed signal  $X_j^f$  by a whitening filter  $F_e$ , the  
4 filtered reconstructed signal  $X_j^f$  being generated according to the equation:

5 
$$X_j^f = X_j - a_1^f X_{j-1} - a_2^f X_{j-2} - \dots - a_n^f X_{j-n}^f$$

6  $X_{j-n}^f$  being a value of filtered reconstructed signal  $X_j^f$  at sample period  $j-n$ ,

7 and

8  $n$  being a number of filter tap coefficients  $a_n^f$  corresponding to the

9 whitening filter  $F_e$ ;

10 updating a predictor coefficient  $a_1^j$  according to the equation:

11 
$$a_1^{j+1} = a_1^j (1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

12  $\delta_1$  and  $g_1$  being proper positive constants, and

13  $F_1$  being a nonlinear function; and

14 updating a predictor coefficient  $a_2^j$  according to the equation:

15 
$$a_2^{j+1} = a_2^j (1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^j)$$

16  $\delta_2$  and  $g_2$  being proper positive constants, and

17  $F_2$  being a nonlinear function.

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1 33. The method of claim 32, further comprising the steps of:

2 updating the filter tap coefficient  $a_i^f$  at each sample period  $j$  according to

3 the generalized equation:

$$a_1^{fj+1} = a_1^{fj}(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

$\delta_1$  and  $g_1$  being proper positive constants, and

$F_1$  being a nonlinear function; and

updating the filter tap coefficients  $a_2^f$  at each sample period  $j$  according to the generalized equation:

$$a_2^{fj+1} = a_2^{fj}(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^{fj})$$

$\delta_2$  and  $g_2$  being proper positive constants, and

$F_2$  being a nonlinear function.

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1 34. The method of claim 32 wherein:

2 the filter tap coefficient  $a_1^f$  is updated according to the equation:

$$a_1^{fj+1} = a_1^{fj} \left( 1 - \left( \frac{128}{32768} \right) \right) + 192 * \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] \text{ and}$$

4 the filter tap coefficient  $a_2^f$  is updated according to the equation:

$$a_2^{fj+1} = a_2^{fj} \left( 1 - \left( \frac{256}{32768} \right) \right) - \left( \frac{1}{32} \right) a_1^{fj} \text{sgn}[X_j^f] \text{sgn}[X_{j-1}^f] + 128 * \text{sgn}[X_j^f] \text{sgn}[X_{j-2}^f]$$

6  $\text{sgn}[\ ]$  being a sign function that returns a value of 1 for a nonnegative  
7 argument and a value of -1 for a negative argument.

1

1 35. The method of claim 34 wherein at every other sample period  $j$ ,

2 the filter tap coefficient  $a_1^{fj+1}$  is maintained in a range  $-12288 \leq a_1^{fj+1} \leq$

3 12288; and

4 the filter tap coefficient  $a^{f+1}_1$  is maintained in a range  $-(15360 - a^{f+1}_2) \leq$   
5  $a^{f+1}_1 \leq (15360 - a^{f+1}_2)$ ;  
6 whereby  $a^{f+1}_1$  is set equal to  $(15360 - a^{f+1}_2)$  when  $a^{f+1}_1 > 15360 - a^{f+1}_2$ ; and  
7 whereby  $a^{f+1}_1$  is set equal to  $-(15360 - a^{f+1}_2)$  when  $a^{f+1}_1 < -(15360 - a^{f+1}_2)$ .

1

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1 36. A machine readable medium embodying instructions executable by a  
 2 machine to perform a method for adapting coefficients in a two pole predictor in  
 3 an adaptive differential pulse code modulation system, the method steps  
 4 comprising:

5 generating a filtered reconstructed signal  $X_j^f$  by a whitening filter, the  
 6 filtered reconstructed signal  $X_j^f$  being generated according to the equation:

$$7 \quad X_j^f = X_j - a_1^f X_{j-1} - a_2^f X_{j-2} - \dots - a_n^f X_{j-n}^f$$

8  $X_{j-n}^f$  being a value of filtered reconstructed signal  $X_j^f$  at sample period  $j-n$ ,

9 and

10  $n$  being a number of filter tap coefficients  $a_n^f$  corresponding to the  
 11 whitening filter;

12 updating a predictor coefficient  $a_1^j$  according to the equation:

$$13 \quad a_1^{j+1} = a_1^j(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

14  $\delta_1$  and  $g_1$  being proper positive constants, and

15  $F_1$  being a nonlinear function; and

16 updating a predictor coefficient  $a_2^j$  according to the equation:

$$17 \quad a_2^{j+1} = a_2^j(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^j)$$

18  $\delta_2$  and  $g_2$  being proper positive constants, and

19  $F_2$  being a nonlinear function.

1

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1 37. A digital circuit embodying instructions to perform a method for adapting  
 2 coefficients in a two pole predictor in an adaptive differential pulse code  
 3 modulation system, the method steps comprising:

4 generating a filtered reconstructed signal  $X_j^f$  by a whitening filter, the  
 5 filtered reconstructed signal  $X_j^f$  being generated according to the equation:

$$6 \quad X_j^f = X_j - a_1^f X_{j-1} - a_2^f X_{j-2} - \dots - a_n^f X_{j-n}^f$$

7  $X_{j-n}^f$  being a value of filtered reconstructed signal  $X_j^f$  at sample period  $j-n$ ,  
 8 and

9  $n$  being a number of filter tap coefficients  $a_n^f$  corresponding to the  
 10 whitening filter;

11 updating a predictor coefficient  $a_1^j$  according to the equation:

$$12 \quad a_1^{j+1} = a_1^j(1 - \delta_1) + g_1 \cdot F_1(X_j^f, X_{j-1}^f, X_{j-2}^f)$$

13  $\delta_1$  and  $g_1$  being proper positive constants, and

14  $F_1$  being a nonlinear function; and

15 updating a predictor coefficient  $a_2^j$  according to the equation:

$$16 \quad a_2^{j+1} = a_2^j(1 - \delta_2) + g_2 \cdot F_2(X_j^f, X_{j-1}^f, X_{j-2}^f, a_1^j)$$

17  $\delta_2$  and  $g_2$  being proper positive constants, and

18  $F_2$  being a nonlinear function.

1

1

1 38. An adaptive differential pulse code modulation system comprising:  
 2 at a first instance:  
 3 means for deriving a difference signal  $E_j$ , the difference signal  $E_j$  being the  
 4 difference between an input signal  $Y_j$  and a predicted signal  $S_j$ ,  $j$  representing a  
 5 sample period;  
 6 means for quantizing the difference signal  $E_j$  to obtain a numerical  
 7 representation  $N_j$ ;  
 8 means for deriving a regenerated difference signal  $D_j$  based on the  
 9 numerical representation  $N_j$ ,  
 10 means for transmitting the numerical representation  $N_j$  to an inverse  
 11 quantizing means coupled to the quantizing means through a network;  
 12 means for deriving a reconstructed input signal  $X_j$ , the reconstructed input  
 13 signal  $X_j$  being the sum of the regenerated difference signal  $D_j$  and the  
 14 predicted signal  $S_j$ ;  
 15 means for generating a filtered reconstructed signal  $X_j^f$ , the filtered  
 16 reconstructed signal  $X_j^f$  being generated according to the equation:  
 17 
$$X_j^f = X_j - a_1^f X_{j-1} - a_2^f X_{j-2} - \dots - a_n^f X_{j-n}^f$$
  
 18  $X_{j-n}^f$  being a value of filtered reconstructed signal  $X_j^f$  at sample period  $j-n$ ,  
 19 and  
 20  $n$  being a number of coefficients  $a_n^f$  corresponding to the means for  
 21 generating a filtered reconstructed signal;

means for generating a predicted signal  $S_{jp}$ , the predicted signal  $S_{jp}$  being at least constituent to predicted signal  $S_j$  and being generated according to the equation:

$$S_{jp} = a_{j1} S_{j-1} - a_{j2} S_{j-2} - \dots - a_{jnp} S_{j-np}$$

$S_{j-np}$  being a value of the predicted signal  $S_j$  at sample period  $j-np$ , and  $n_p$  being a number of predictor coefficients  $a_{jnp}$  corresponding to the means for generating a predicted signal; and

feedback means for applying the predicted signal  $S_j$  to the means for deriving a reconstructed input signal  $X_j$ ;

at a second instance:

the inverse quantizing means for deriving the regenerated difference signal  $D_j$  from the numerical representation  $N_j$ ;

second means for deriving a reconstructed input signal  $X_j$ , the reconstructed input signal  $X_j$  being the sum of the regenerated difference signal  $D_j$  and the predicted signal  $S_j$ ;

second means for generating a filtered reconstructed signal  $X_j^f$ , the filtered reconstructed signal  $X_j^f$  being generated according to the equation:

$$X_j^f = X_j - a_{f1}^f X_{j-1} - a_{f2}^f X_{j-2} - \dots - a_{fn}^f X_{j-n}^f$$

$X_{j-n}^f$  being a value of filtered reconstructed signal  $X_j^f$  at sample period  $j-n$ , and

$n$  being a number of coefficients  $a_{fn}^f$  corresponding to the second means for generating a filtered reconstructed signal;

44 second means for generating a predicted signal  $S_{jp}$ , the predicted signal  $S_{jp}$   
45 being at least constituent to predicted signal  $S_j$  and being generated according  
46 to the equation:

47 
$$S_{jp} = a_1 S_{j-1} - a_2 S_{j-2} - \dots - a_{n_p} S_{j-n_p}$$

48  $S_{j-n_p}$  being a value of the predicted signal  $S_j$  at sample period  $j-n_p$ , and  
49  $n_p$  being a number of coefficients  $a_{n_p}$  corresponding to the means for  
50 generating a predicted signal; and  
51 feedback means for applying the predicted signal  $S_j$  to the means for  
52 deriving a reconstructed input signal  $X_j$ .